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Uncovered Interest Parity and the Risk Premium

Dandan Li, Atanu Ghoshray and Bruce Morley

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Uncovered Interest Parity and the Risk Premium

By

Dandan Li
University of Bath, UK

Atanu Ghoshray
University of Bath, UK

and

Bruce Morley*
University of Bath, UK

Abstract

The aim of this study is to analyze the potential risk premium inherent in the uncovered interest parity (UIP) condition. In this approach the GARCH class models, including Component GARCH are used to measure the time-varying risk premium and the results show that it is significant in most countries studied in this analysis. This suggests that risk is an important part of modeling exchange rates and needs to be considered in both empirical and theoretical models. In general, the results suggest emerging countries work better in terms of UIP and the risk premium than developed countries.

Keywords: Risk premium; Uncovered Interest Parity; Component GARCH-in-mean

JEL Classifications: F30, G15

* Corresponding Author: B. Morley, Department of Economics, University of Bath, Bath, UK, BA2 7AY, e-mail: bm232@bath.ac.uk, Tel: +44 1225 386497, Fax: +44 1225 383423.

1. Introduction

With the development of international financial markets, financial instruments have contributed to international capital market integration by increasing capital mobility between developed and emerging countries. Therefore asset parity conditions have become a vital consideration for all international investors. Uncovered interest parity (UIP) is one of the most important theoretical relations used in analytical work in both international finance and macroeconomics and is also a key assumption in many models of exchange rate determination.

UIP implies that the interest rate differential should be equal to the exchange rate change. Otherwise, arbitragers could receive a higher return through selling foreign currency and investing in domestic currency if the interest rate differential is greater than the expected depreciation of the domestic currency against the foreign currency. However, in reality, low interest rate currencies tend to depreciate relative to high interest rate currencies. This is inconsistent with UIP and has been confirmed by an extensive literature for different countries and periods. Overall there has been no consensus on how to explain the failure of UIP. A number of explanations for the deviations from UIP include the failure of rational expectations, the time-varying risk premium and the peso problem. The time-varying risk premium is one of the most frequently cited reasons leading to the failure of UIP (see Froot and Thaler 1990; McCallum 1994; Meredith and Chinn 1998). Therefore, it is necessary to continue investigating whether the time-varying risk premium could affect the validation of UIP especially over the periods of the Asian financial crisis and the recent credit crisis.

The two contributions of this paper are as follows. First of all, we use different econometrics models (GARCH-in-mean and Component GARCH-in-mean) to assess the time-varying risk premium which is measured as the conditional standard deviation in the UIP condition. Following the financial and credit crises over the sample period considered in this study, there has been a rapid change in risk across the world. To account for this, we use CGARCH rather than other GARCH models as this reflects the substantial change in risk experienced recently and separates out the permanent and transitory risk. The CGARCH is a superior volatility model for exchange rates and is widely used in finance, as it can distinguish the long-run and short-run volatility components and can describe volatility dynamics better than other GARCH models (see Christoffersen et al., 2006). However this is the first time it has been used to measure the risk premium in UIP, which could shed some light on the importance of both the permanent and transitory UIP risk premium in the context of investment strategies. Secondly, we select both developed and emerging countries for comparison. The majority of the literature on UIP concentrates on low-inflation and floating exchange rate regime countries (developed countries). However Flood and Rose (2002) demonstrate that countries which have high exchange rate and interest rate volatility work better regarding UIP than others. Comparing the different UIP results between developed and emerging countries could help us to understand the implications for monetary policy for both sets of countries. Therefore, we have also considered emerging countries which face financial or credit crises and have a mix of fixed and floating exchange rate regimes.

The main result of this study is that UIP including the risk premium works better than previous studies which exclude it, although it still does not always hold. However, it gives positive and significant coefficients for most emerging countries. This study also finds that the coefficient of the risk premium is significant in most countries, suggesting that risk is an important part of modeling exchange rates and needs to be considered in both empirical and theoretical models. Moreover, developed countries prefer the GARCH-M model for forecasting, whilst for emerging countries the CGARCH-M model works best.

The remainder of this paper is organized as follows. Section 2 presents the theory of UIP and the previous literature. In section 3, the method and data used are described. Section 4 presents the main empirical analysis in order to see whether UIP holds and Section 5 concludes and suggests further areas of study.

2. Uncovered Interest Parity and the Risk Premium

2.1 Uncovered Interest Parity

UIP suggests that the domestic currency is expected to depreciate when the domestic interest rate exceeds the foreign interest rate. The interest rate differential should equal the expected exchange rate change. However, the problem is that UIP does not hold well empirically. Most empirical evidence on developed economies suggests that exchange rate changes and interest rate differentials are negatively correlated, with high domestic nominal interest rates predicting an appreciation of the domestic currency (see Froot and Thaler, 1990).

UIP is not an arbitrage condition between investing in domestic currency denominated assets and foreign currency denominated assets, so UIP can be expressed as:

$$(1+i_{t,k}) = (1+i_{t,k}^{*})\frac{E_t S_{t+k}}{S_t} \tag{1}$$

where $i_{t,k}$ represent the domestic interest rate at time t of maturity k, $i_{t,k}^*$ is the foreign interest rate, S denotes the exchange rate which is the domestic currency price of a unit of foreign currency and E_t is the expectations at time *t*. Alper and Ardic (2006) reported some assumptions which are used to estimate this equation in order to allow interpretation of UIP condition. These assumptions can be stated as follows: investors are risk neutral, there are no capital controls, transaction costs are negligible, underlying assets are identical in terms of liquidity, maturity and default risk and there is a sufficient number of investors with ample funds available for arbitrage. We follow the previous literature by taking natural logarithms of the above equation (1) and imposing rational expectations, and then get the following empirical equation for UIP:

$$\Delta s_{t+k} = s_{t+k} - s_t = \alpha + \beta(i_{t,k} - i_{t,k}^*) + \varepsilon_{t+k} \quad (2)$$

where Δs_{t+k} is the change in the log of the spot exchange rate over k periods and $(i_t - i_t^*)$ is the current k period home interest rate less the k period foreign interest rate. The null hypothesis for UIP is that $\alpha = 0, \beta = 1$. We also expect that the error term is Gaussian and stationary.

The basic UIP relationship has been researched extensively, Froot and Thaler (1990) summarize the coefficient results from 75 published studies, with most giving a negative coefficient and those with positive coefficients having less than the hypothesized value of one, the average value of the coefficient is -0.88. A slightly different approach to exchange rate expectations was used by Berk and Knot (1999), where the expectation is generated from purchasing power parity (PPP) rather than from the actual exchange rate data, which is different to some previous research because it didn't assume rational expectations. They also use long horizon data instead of short horizon. The results demonstrate that UIP holds to some extent and it improves on the UIP tests by Froot and Thaler (1990) and McCallum (1994). However, the problem for this paper is that it is hard to explain whether UIP is holding due to the use of PPP to generalize exchange rate expectation or the long-run data used. Chinn and Meredith (2000) demonstrate that UIP hold s using long-term horizons with coefficients shifting from negative values to positive ones, around unity, when the horizon increases. They find the average value for the coefficient is –0.8 for the 3, 6 and 12 month horizons for the period 1980 to 2000 and 0.87 for 5-year horizon. UIP seems to hold better at long-term horizons. Flood and Rose (2002) test UIP using high frequency daily data for 23 developed and emerging countries during the 1990s. They found that UIP works better in the crisis periods and has a positive coefficient in some countries although not always insignificantly different from one. We will use monthly data with short-term maturity (1 month) rather than long-term maturity, as the forecast errors of the exchange rate are more likely to be small.

2.2 Risk Premium

Most empirical tests of UIP are based on assumptions of rational expectations and risk neutrality, one obvious explanation for the UIP failure ($\beta<1$ and even being negative) is the existence of a time-varying risk premium. The time-varying risk premium is a part of the OLS residuals and its correlation with the exchange rate change causes the estimated beta coefficient to be biased. If the domestic interest rate rises (relative to the US interest rate), investment in domestic assets becomes relatively more risky. If market participants are risk averse, then the forward rate will equal the expected spot exchange rate plus a risk premium (see Meredith and Chinn, 1998; Chinn, 2006).The risk premium δ is written as:

$$f_t = E_t s_{t+1} + \delta_{t+1} \qquad (3)$$

If we assuming that CIP holds ($f_t - s_t = i_t - i_t^*$), the equation could change to:

$$i_t - i_t^* = E_t s_{t+1} - s_t + \delta_{t+1} \qquad (4)$$

We rearrange the equation (4) and get the following equation (5)

$$E_t s_{t+1} - s_t = i_t - i_t^* - \delta_{t+1} \qquad (5)$$

In this situation, the interest rate differential could not be interpreted as the expected change in the exchange rate. The interest differential is equal to the expected change in the exchange rate plus a risk premium.

Under rational expectation $s_{t+1} = E_t s_{t+1} + \varepsilon_{t+1}$, the UIP model considers the risk premium being expressed as:

$$s_{t+1} - s_t = i_t - i_t^* - \delta_{t+1} + \varepsilon_{t+1} \qquad (6)$$

$$s_{t+1} - s_t = \alpha + \beta(i_t - i_t^*) + \gamma\delta_{t+1} + \varepsilon_{t+1}$$

The empirical formulation of the risk premium, following previous research by Domowitz and Hakkio (1985) and Tai (1999) is defined as:

$$\delta_{t+1} = \alpha_0 + \gamma\sigma_{t+1} \qquad (7)$$

where σ_{t+1} is the conditional component of the standard deviation of the error term. The risk premium has a constant component (α) and a time-varying component, which is the conditional standard deviation. If both α and γ are insignificantly different from zero, there is no risk premium. If $\alpha \neq 0$ but $\gamma=0$, there is a constant risk premium. Only when $\gamma \neq 0$ does the time-varying risk premium exist. The previous finding of $\beta<0$ means that the increase in the interest differential is combined with the decline in the expected change in the exchange rate and a larger rise in the risk premium. Investors are demanding a large risk premium for holding risky high interest rate currencies and that those currencies are expected to appreciate rather than depreciate. Holders of the risky currencies are compensated both by higher interest rates and by currency appreciation.

Froot and Frankel (1989) use survey data on exchange rate expectations to decompose the deviations from UIP into deviations caused by expectation error and a time-varying risk premium. They find that the largest part of deviations from UIP are caused by expectation error, while the time-varying risk premium plays a minor role. However, the results of Taylor (1989) and Cavaglia *et al*. (1993) indicate an important role for the time-varying risk premium rather than the expectation error. Froot and Thaler (1990) demonstrate in their paper that the risk premium significantly affects UIP. Anker (1999) proves that when the correlation between the risk premium and the change in the exchange rate is negative, the estimated coefficient on the interest differential is less than zero. McCallum (1994) and Meredith and Chinn (1998) point out that the risk premium is the main reason leading to UIP failure over the short-term horizon. However, in the long term, exchange rates are determined by fundamentals. Therefore, UIP works much better at explaining the relationship between interest differential and the exchange rate change over the long horizons. Berk and Knot (2001) following the seminal work of Engle et al. (1987), allow for a time-varying risk premium by estimating the UIP relationship as the conditional mean in an ARCH-in-mean model. Poghosyan *et al.* (2008) test UIP in Armenia and find that UIP holds better than other studies and there exists a positive time-varying risk premium based on the GARCH-M model. Melander (2009) tests for UIP in Bolivia (emerging country) and found that UIP also does not hold, but the deviation from UIP is smaller than before. He tests three factors which induce UIP deviation, which are the peso problem, time-varying risk premium and rational expectations. He uses the GARCH-M model to test the risk premium in UIP and proves that UIP still does not hold.

Earlier empirical studies on the UIP condition mostly focus on developed economies rather than emerging markets because of a lack of data. Most studies testing UIP are based on the data from developed countries with floating exchange rates and prove that UIP does not hold. Recently, increases in the degree of financial liberalization in emerging markets enabled many researchers to analyze the foreign exchange market in these countries. Many researchers have studied the UIP condition in emerging countries with fixed exchange rates. Flood and Rose (1996) find that UIP holds better for fixed exchange rates than floating exchange rates. But they said there is no theoretical reason to explain this difference of exchange rate regime change. Flood and Rose (2002) suggest that UIP holds better in crisis countries which have high exchange rate and interest rate volatility. Bansal and Dahlquist (2000) find that the forward premium puzzle is only present in developed countries where its interest rate is lower than the interest rate of the US, not in the emerging countries. Frankel and Poonawala (2006) have however found small deviations from UIP in emerging countries.

3. Methodology

3.1 GARCH-M Model

ARCH has been proposed by Engle (1982). It is a method to explain why large residuals tend to clump together. However, volatility is more persistent than explained by the ARCH model. The conditional variance in the GARCH model depends on both lagged variance and lagged residual. The GARCH class models are widely used with time series financial data. The GARCH-in mean (GARCH-M) model introduced by Engle, Lilien and Robins (1987) was designed to capture the relationship between return and risk, such as with the CAPM. The applications of GARCH-M models to stock returns, interest rates and exchange rates can be found in Bollerslev, Chou and Kroner (1992). We follow the paper of Berk and Knot (2001) and Melander (2009) and add the conditional standard deviation as a time-varying risk premium in the mean equation to construct the GARCH-M model. The GARCH-M model used in UIP empirical analysis is written as follows:

$$\begin{aligned} s_{t+1} - s_t &= \alpha + \beta(i_t - i_t^*) + \gamma\sigma_{t+1} + \varepsilon_{t+1} \\ \sigma_{t+1}^2 &= \delta_0 + \varphi_1\varepsilon_t^2 + \varphi_2\sigma_t^2 \end{aligned} \tag{8}$$

where σ_{t+1} is the standard deviation and denotes the time-varying risk premium that directly affects the exchange rate.

3.2 CGARCH-M Model

We used the component GARCH (CGARCH) model proposed by Engle and Lee (1999) in our research as many researchers find is a superior volatility model[1]. This

[1] Christoffersen et al. (2006) find that distinguish short-run and long-run components enable CGARCH model to describe volatility dynamics better than GARCH model.

model decomposed volatility into two components, the long-run trend[2] and short-run deviations from that trend. The CGARCH model has proved useful in the analysis of exchange rate volatility as suggested by Black and McMillan (2004) and Byrne and Davis (2005). This is because the exchange rate has a strong long-run volatility trend. This model can be seen as an extension of the GARCH model with the conditional variance mean-reverting to a long–run trend level. However as yet no one has used it to test the risk premium in UIP. This paper uses the asymmetric CGARCH-M model based on GJR (1993). The model is described by the following set of equations:

$$s_{t+1} - s_t = \alpha + \beta(i_t - i_t^*) + \gamma\sigma_{t+1} + \varepsilon_{t+1} \tag{9}$$

$$q_{t+1} = \varphi_1 + \varphi_2(q_t - \varphi_1) + \varphi_3(\varepsilon_t^2 - \sigma_t^2) \tag{10}$$

$$\sigma_{t+1}^2 = q_{t+1} + \varphi_4(\varepsilon_t^2 - q_t) + \varphi_5 D_t(\varepsilon_t^2 - q_t) + \varphi_6(\sigma_t^2 - q_t) \tag{11}$$

where D_t is a dummy variable for the asymmetric effect, $D_t=1$ for $\varepsilon_t<0$, $D_t=0$ otherwise, q_{t+1} is the long-run component of the conditional variance which reflects shocks to economic fundamentals, σ_{t+1}^2-q_{t+1} is the short-run component which is more volatile and driven by market sentiment. In the long-run component of volatility equation, the AR coefficient (φ_2) of permanent volatility should exceed the coefficients ($\varphi_4+\varphi_6$) in the transitory component which then implies that the model is stable and short-run volatility converges faster than the long-run. The coefficient of the forecast error φ_3 shows how shocks affect the permanent component of volatility. In several previous instances, we find that the coefficient of the autoregressive term in the long-run trend equation is equal to or very close to one. We include an asymmetric term in the model to test the leverage effect. The reason we add an asymmetric term

[2] An alternative to the CGARCH model for long memory in conditional variance has been provided by the FIGARCH model.

into the CGARCH-M model follows the work of Guimarães and Karacadag (2004), who modeled the exchange rate volatility in emerging market currencies and as with them, we also expect it to be significant.

3.3 Data

The data set consist of monthly data of the exchange rate and interest rate for both developed and emerging countries. The time periods for the various countries are different due to data limitations. The United Kingdom, Australia, Japan and Switzerland are from 1986 to 2009 and Canada is from 1990. Other emerging countries due to a lack of data will start from the early 1990's. We collected data from two sources, Datastream and BIS (Bank for International Settlements). The exchange rate data was obtained from both the BIS and Datastream together and is the average value for each month. The 1 month interest rate data are collected from Datastream. Also note that both domestic and foreign interest rates are annualized.

4. Empirical Analysis

Table 1 presents the basic regression results. The range for the coefficient of the interest differential (β) from the OLS tests is from -2.1875 to 1.0768. The results for the developed countries are quite similar to previous empirical studies which have negative β coefficients. However, most are insignificant except Japan. The β coefficients from emerging countries are positive but mostly insignificant. Only Russia gives us positive and significant result. From Table1, half of the p-values demonstrate that UIP is valid but the coefficient β is insignificant, which mean there is still some problem with the OLS estimation. The R-square is extremely low, which also suggests that the interest rate differential does not explain the exchange rate change very well. Then we present the Q-statistic for serial correlation. The p-value for all 36 lags is nearly zero which means that there is autocorrelation between the residuals (the result is not shown in Table 1). Next, we are going to do other residual tests (ARCH effect test). The reason for examining the ARCH effect is that the volatility of UIP deviations (risk premium) might be one reason leading to UIP being invalid. The null hypothesis is no ARCH effect. Half of the results reject the null hypothesis and prove that there is an ARCH effect in the model. The above misspecification and diagnostic tests show that OLS is not the best model for UIP testing because there are problems such as serial correlation and the ARCH effect. In the following sections we will test GARCH class models to decide whether the risk premium affects the UIP.

Table 2 and Table 3 display the unit root test results for the exchange rate change and interest rate differentials. The Augmented Dickey-Fuller (ADF) test provides strong evidence that the exchange rate change is stationary at the 1% confidence level. However the unit root results for the interest rate differential are contradictory. From the ADF test, six out of ten countries are stationary, but with the DF-GLS test it is only three countries and with Ng-Perron it is five. This result indicates that the interest rate differential is more persistent than the exchange rate change. It is also an interesting finding that exchange rate change is always stationary but the interest rate differential is nonstationary which is consistent with other studies (see Goh, Lim and OLekalns, 2006; de Brouwer, 1999). They also mention that it is caused by substantial capital controls. Further unit root research on the interest rate differential based on the Zvoit-Andrews test[3] (structural break) and TAR/M-TAR tests (asymmetric adjustment)

[3] The results from the Zvoit-Andrews test and TAR/M-TAR tests are available from the authors on request.

proved that the interest rate differential is stationary with asymmetric adjustment.

Table 4 illustrates the estimated risk-adjusted UIP results from a GARCH-M model under generalized error distribution (GED) using maximum likelihood estimation (MLE)[4]. It is apparent that the coefficients of the interest differential from developed countries are all negative and significant. It ranges from -0.8 to -2.5. This negative coefficient means that an increase in the interest differential will lead to a decrease in the expected change of the exchange rate. This is consistent with previous literature. However, the β coefficients are all positive for emerging countries and significant except for Mexico. The Wald test on the coefficient of the interest differential being equal to one is rejected by all countries except Thailand, which is significant at the 1% level. Moreover, the coefficients on the conditional standard deviations are positive and significant for the UK, Malaysia and Thailand. However, Canada, Switzerland and Russia have negative and significant coefficients on the risk premium. This negative coefficient corresponds to the mean-variance theory. It implies that when there is an increase in risk (standard deviation), the deprecation of the home currencies decreases, and the expected return from holding this home currency increases. The risk averse investors required more return when they face higher risk. This negative coefficient for the risk premium is also found by Melander (2009) when testing the UIP condition with a basic GARCH model in Bolivia. The estimated risk premium consists of two parts, the constant risk premium (α) and the time-varying part (γσ). The Wald test rejects the null hypothesis of no risk premium in Canada, Switzerland, Brazil, Malaysia and Russia. However, the other countries did not reject

[4] Tai (1999) mentioned that GED take into account the leptokurtosis which is found in most financial data including exchange rates.

the null, which indicates the risk premium is not significant. Thelack of a risk premium was also found by Domowitz and Hakkio (1985), who could not reject the null hypothesis of no risk premium for the currencies of five industrial countries using an ARCH-M model and with Baillie and Bollerslev (1990) who fail to find a time-varying risk premium for four European countries based on a multivariate GARCH model. The insignificant risk premium coefficients of these five countries may result from either a poor measure of risk or the misspecification of the model. In other words, the conditional standard deviation may not be the proper measure of risk or the univarite GARCH-M model is not an appropriate econometric model to estimate the risk premium. But there is still an improvement when testing UIP including a risk premium using a GARCH-M model rather than the basic OLS model. Furthermore, the estimated coefficients of the ARCH and GARCH term are all significant at the 1% level except in Japan.

The conditional standard deviation from the GARCH-M model is shown in Figure 1. We find that developed countries have relatively low conditional standard deviation compared with other emerging countries. This is reasonable because of the stable policy and higher credit rating. Combined with the results of the β coefficients, we find that UIP works differently for countries whose exchange rate and interest rate display high or low standard deviation. The result found here that low standard deviation tends to cause the failure of UIP is also found by Ichiue and Koyama (2008).

The results for the CGARCH-M model are presented in Table 5. The intercept coefficient is significant at the 5% and 10% level separately and negatively. The intercept in the UK, Japan, Switzerland, Malaysia, Thailand and Russia is significant which means that there is a constant risk premium. This intercept takes into account of each country's specific financial systematic risk such as the liquidity of the foreign exchange market. The coefficients of the time-varying risk premium are more significant than the GARCH-M model, and the positive β coefficients have increased and are close to 1. The Wald test for no risk premium is rejected for all countries except for Australia, Canada and Mexico. The Wald test for β=1 is rejected in most countries, however, Malaysia, Thailand and Russia all support the UIP condition. In the long-run trend equation, we find all countries have a positive and mostly a significant constant (φ_1), but the magnitude is extremely small and nearly zero. The coefficient (φ_2) of the lagged permanent volatility is large and highly significant except for Japan. It is close to one which means the trend persistence is very high and the permanent volatility converges to its mean level slowly. As we know $0<\varphi 2<1$ and the long run component converges to its mean. However, only half of the results demonstrate that the short-run volatility converges to its mean of 0 (the sum of the coefficients being between zero and one). While the sum of the coefficients of the transitory component ($\varphi_4+\varphi_6$) is lower than the coefficient (φ_2) of the lagged permanent volatility, this implies that our model is stable and mean reversion is slow in the long run. Therefore, the long-run volatility is more persistent than the short-run. The larger long-run volatility component indicates that the risk premium is mainly driven by shocks to economic fundamentals rather than shifts in market sentiment. This result is similar to previous literature, such as Black and McMillan (2004), Guimarães and Karacadag (2004) and Byrne and Davis (2005). There are five out of ten significant forecast error parameters (φ_3) capturing the influence of the driving force for the time-dependent movement of the permanent component. The asymmetric coefficient (φ_5) is negative and significant in the UK, Australia and Brazil which implies the presence of a transitory leverage effect in the transitory component equation. But it is positive and significant in Japan, Switzerland, Mexico, Malaysia and Thailand. Therefore, UIP remains invalid in developed countries, but holds in Russia, Thailand and Malaysia.

Figure 2 shows the estimated transitory and permanent component of volatility. The transitory component of the volatility (the green line) is much smaller than the permanent volatility (the red line) for all the countries. And in most countries, the transitory component is much more volatile than the permanent component. The transitory volatility is driven by market sentiment which is maybe related to short-run speculative pressures. The permanent volatility is based on the fundamentals of the macroeconomy, such as the goods markets, where it is assumed adjustment takes a longer while than with the transitory volatility, due to the usual inertia in such markets. This implies that transitory shifts in financial market sentiment tend to be less important determinants of volatility than shocks to the underlying macroeconomic fundamentals. It is consistent with the results from Pramor and Tamirisa (2006) who analyse exchange rate volatility. During the crises periods the short-run volatility approximates much more closely to the long-run which reflects the importance of short-term turbulence in the international financial markets. Separating permanent and transitory risk premium emphasizes the importance of assessing the real impact of uncertainty on investment management because the change in the determinants of investment have different effects depending on whether this uncertainty is permanent or transitory (see, Byrne and Davis, 2005).

The results for the forecasting performance are shown in Tables 6 and Table 7. Here the model that exhibits the lowest value for its error measurement is considered to be the best. According to the root mean square error (RMSE) statistic and mean average error (MAE), the GARCH-M model works better in all developed countries and the CGARCH-M model is preferred by emerging countries except Russia. This is because the risk is time varying in emerging countries whereas in developed countries it tends to be mean reverting.

5. Conclusion

The main finding of this paper is that the risk premium is significant in most countries studied in this analysis. Including the risk premium in the UIP condition improves on the original model, as the β coefficient becomes more significant with a risk premium included in the model than in the basic OLS model, although UIP still does not hold in many countries. This result suggests that risk is an important part of modeling the exchange rate and needs to be considered in both empirical and theoretical models. In addition the risk needs to be considered in terms of the permanent and transitory components, where the permanent component is found to have the greatest effect, suggesting it is volatility from the macroeconomic fundamentals that are the primary determinant of exchange rates. This study also finds that in general emerging countries work better in terms of UIP and the inclusion of the risk premium than developed countries, as the β coefficient in emerging countries is positive and close to unity. Moreover, the CGARCH-M model outperforms other GARCH models when modeling UIP, in terms of the risk premium as it considers both the long-run and short-run volatility components.

When forecasting the exchange rate we find although the GARCH model works best for developed countries, the CGARCH model is superior for forecasting emerging countries, due to the greater exchange rate volatility found in emerging economies. Further research could incorporate a longer data span as more data becomes available and incorporate the risk premium into alternative models of exchange rate determination, such as the portfolio balance model.

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Table 1 OLS results

	α	β	Wald test		ARCH effect test	
			χ^2	p-value	F statistic	p-value
UK	-0.0002	-0.0295	1.3946	0.4979	38.6748	0.0000
AUS	0.0012	-0.8156	5.1147	0.0775	12.4057	0.0005
JAP	-0.0070**	-2.1875**	9.8570	0.0072	14.6976	0.0002
CAN	-0.0001	0.0485	2.0281	0.3627	1.5073	0.2208
SWI	-0.0031	-1.3372	3.7904	0.1503	0.2888	0.5914
BRA	0.0031	0.1571	12.0729	0.0029	0.3026	0.5830
MEX	0.0058	0.1821	5.5142	0.0635	3.0429	0.0827
MAL	0.0015	0.4763	6.3549	0.0417	56.233	0.0000
THA	-0.0010	1.0768	0.2349	0.8892	1.5679	0.2119
RUS	0.0023	0.5836***	5.5384	0.0627	7.75E-06	0.9978

Note: The OLS result is run by the equation (2). The Wald test is a joint test of null hypothesis H_0: α=0, β=1. . ***, ** and * denote statistical significance at 1%, 5% and 10% level.

Table 2 Exchange rate change

	ADF	DF-GLS	Ng-Perron	
	intercept	Intercept	MZ_α	MZ_t
UK	-7.6202***	-1.2332	-2.6495	-1.0963
AUS	-10.496***	-2.2835**	-3.9309	-1.1178
JAP	-3.8790***	-1.0809	-1.3892	-0.8327
CAN	-3.8679***	-5.3184***	-44.293	-4.4080
SWI	-11.315***	-1.7344	-3.6724	-1.3312
BRA	-10.987***	-10.982***	-83.901	-6.4612
MEX	-4.2313***	-3.0826***	-11.089	-2.3265
MAL	-4.7127***	-1.3354	-2.0906	-0.9565
THA	-5.6943***	-4.8595***	-32.774	-4.0451
RUS	-5.6917***	-1.6421*	-4.7981	-1.4227

Table 3 Interest rate differential

	ADF	DF-GLS	Ng-Perron	
	intercept	Intercept	MZ_α	MZ_t
UK	-2.6211*	-1.2106	-5.1906	-1.4859
AUS	-1.6213	-0.3390	-0.2336	-0.2055
JAP	-2.7543*	-1.8148*	-7.6415	-1.8999
CAN	-2.8524*	-0.4195	-0.7065	-0.4507
SWI	-2.4776	-1.7575	-9.9998	-2.1697
BRA	-3.8831***	-0.1359	-0.1915	-0.1401
MEX	-1.8171	-1.6341*	-6.6102	-1.7619
MAL	-2.9323**	-1.7024*	-5.8248	-1.7063
THA	-2.1471	-1.4932	-6.5945	-1.7772
RUS	-4.3745***	-0.1886	-0.1083	-0.0951

Note: ADF test use the general to specific approach to select the number of lags. DF-GLS and Ng-Perron tests use modified information criteria (MIC). ***, ** and * denote statistical significance at 1%, 5% and 10% level.

Table 4 GARCH-M model

	α	β	γ	φ_1	φ_2	β=1	α =γ=0
UK	-0.0206**	-2.1743***	1.0109**	0.1641***	0.6935***	0.0001	0.1041
AUS	-0.0008	-1.1840*	0.0935	0.1579***	0.7910***	0.0008	0.7682
JAP	0.0382	-2.5467***	-1.6682	0.1113	-0.0120	0.0001	0.1377
CAN	0.0065**	-0.7871*	-0.4283**	-0.0239***	1.0356***	0.0002	0.0226
SWI	0.0750*	-1.8072**	-2.9064**	-0.0596***	0.7640***	0.0003	0.0000
BRA	0.0042***	0.1537***	-0.0189	2.9294***	0.5116***	0.0000	0.0000
MEX	-0.0034	0.0666	0.1267	0.3509***	0.5658***	0.0000	0.3660
MAL	-0.0008***	0.4535***	0.2017***	0.4489***	0.7477***	0.0000	0.0000
THA	-0.0030*	0.4458*	0.1404*	0.4597***	0.7115***	0.0298	0.1827
RUS	0.1451	0.3056***	-1.6622**	-0.0092***	0.5295***	0.0000	0.0000

Note: the GARCH-M model is expressed in equation (8). The p-value of the Wald tests of β=1 and α =γ=0 are in the table.

Table 5 CGARCH-M model

	α	β	γ	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6	β=1	α =γ=0
UK	-0.0381*	-2.3395***	1.8824**	0.0005***	0.7055***	0.1136	0.0964	-0.2666**	-0.1941	0.0000	0.0970
AUS	0.0016	-1.4183**	0.0105	0.0007**	0.9639***	0.0816	0.2624*	-0.3783*	0.2803	0.0001	0.6589
JAP	0.0569***	-2.9683***	-2.5817***	0.0006***	0.1393	0.0021	-0.1195	0.2271***	0.0964	0.0000	0.0000
CAN	0.0052	-0.7102	-0.3066	0.0025	0.9992***	0.0395*	0.0043	0.1407	0.2125	0.0063	0.3127
SWI	0.0722*	-2.0599**	-2.7819*	0.0007***	0.6250***	-0.1017	0.0458	0.0280	-0.0357	0.0004	0.0021
BRA	0.0036	0.2574***	-0.2133***	0.0010	0.9778***	0.2767***	0.2495**	-0.3938**	0.4170	0.0000	0.0178
MEX	-0.0020	-0.0862	0.1317	0.0010**	0.8548***	0.1935	0.0630	0.4567**	0.2986	0.0000	0.3685
MAL	-0.0046**	0.2143	0.3885***	0.0002***	0.8859***	0.1887***	0.1101**	0.1037**	-0.6065***	0.0210	0.0000
THA	-0.0082***	1.1516***	0.3569***	0.0005	0.9883***	0.1595*	0.0932	0.3445*	-0.2535***	0.5061	0.0000
RUS	0.1315***	0.6108***	-2.3717***	0.0037***	0.9123***	-0.0044**	-0.0006	0.0521	0.7587	0.0269	0.0000

Note: the CGARCH-M model is expressed in equation (9). The p-value of the Wald tests of β=1 and α =γ=0 are in the table. ***, ** and * denote statistical significance at 1%, 5% and 10% level

Table 6 Forecasting GARCH-M

	RMSE	MAE	TIC	BP	VP	CP
UK	0.04053	0.03092	0.97576	0.17129	0.72671	0.10200
AUS	0.06271	0.04290	0.97172	0.03314	0.92338	0.04348
JAP	0.03490	0.02880	0.89171	0.00619	0.80771	0.18610
CAN	0.06153	0.05277	0.78341	0.67218	0.31602	0.01180
SWI	0.02462	0.01993	0.91473	0.00003	0.91366	0.08631
BRA	0.59665	0.31382	0.89153	0.23752	0.63436	0.12813
MEX	0.05297	0.03544	0.98717	0.04644	0.95156	0.00200
MAL	0.03213	0.02121	0.86173	0.14981	0.48835	0.36183
THA	0.02278	0.01947	0.75889	0.04762	0.51045	0.44193
RUS	0.05010	0.03792	0.92324	0.07718	0.86962	0.05320

Table 7 Forecasting CGARCH-M

	RMSE	MAE	TIC	BP	VP	CP
UK	0.04088	0.03127	0.97086	0.18286	0.71121	0.10593
AUS	0.06260	0.04317	0.98019	0.02884	0.92330	0.04786
JAP	0.03530	0.02923	0.89220	0.00539	0.76096	0.23366
CAN	0.10431	0.09850	0.83095	0.89169	0.10506	0.00325
SWI	0.02471	0.02010	0.90326	0.00056	0.93876	0.06068
BRA	0.07181	0.05109	0.84655	0.21294	0.64583	0.14124
MEX	0.05266	0.03540	0.96471	0.04053	0.94449	0.01498
MAL	0.02868	0.01510	0.99355	0.04173	0.95655	0.00172
THA	0.02136	0.01813	0.75976	0.07061	0.83649	0.09291
RUS	0.05505	0.04113	0.93037	0.16972	0.61045	0.21983

Note: The Theil inequality coefficient (TIC) should lie between zero and one, where zero indicates a perfect fit. The bias proportion (BP) tells us how far the mean of the forecast is from the mean of the actual series and variance proportion (VP) demonstrates how far the variation of the forecast is from the variation of the actual series. Both of them should be small if the forecast model is good. The covariance proportion (CP) measures the remaining unsystematic forecasting errors. The sum of these three parts should be equal to 1.

Figure 1 Conditional Standard Deviation GARCH-M

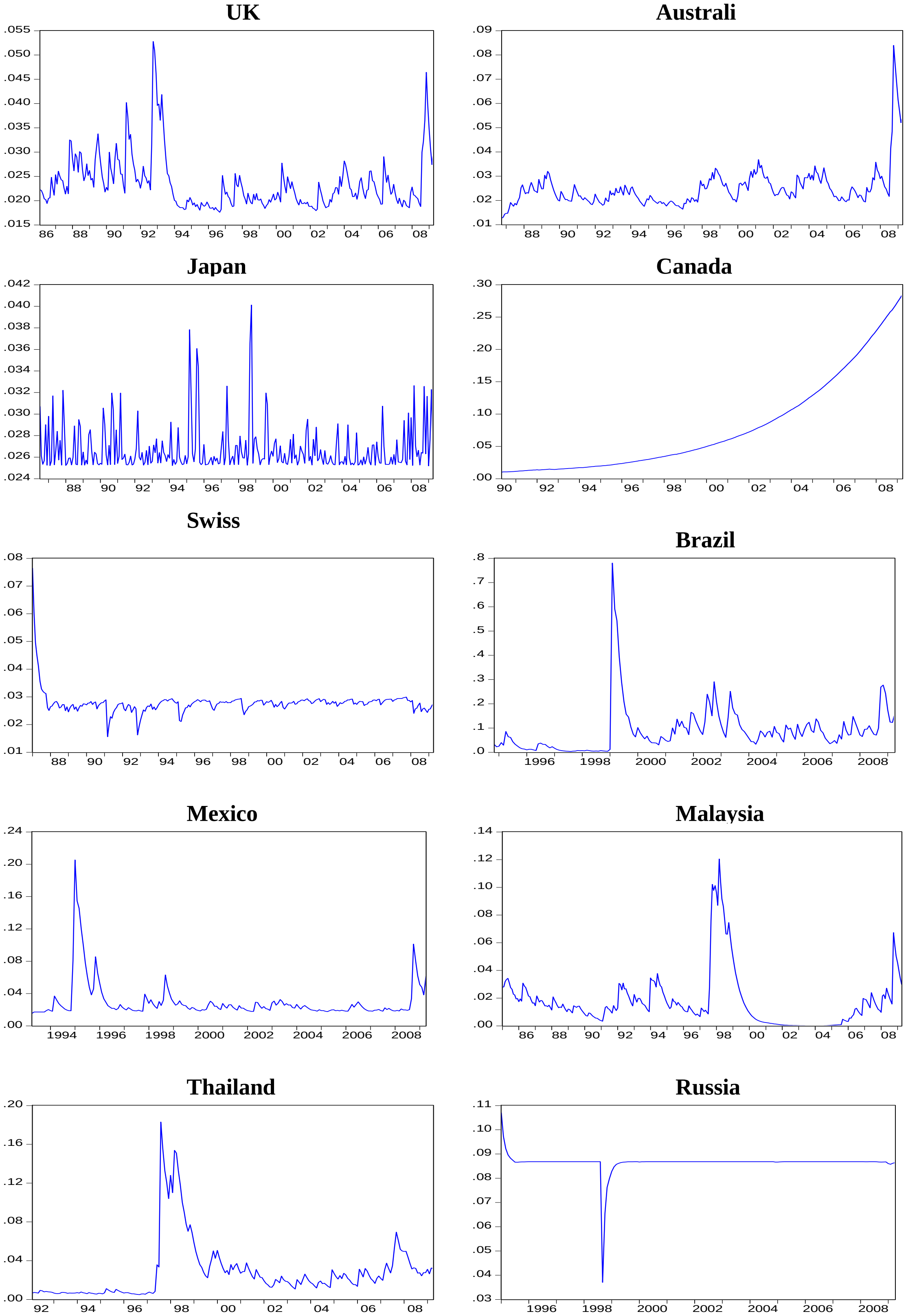

Figure 2 Conditional Standard Deviation CGARCH-M